

Subject \Rightarrow Chemistry

Chapter \Rightarrow Physical properties
of liquids

Topic \Rightarrow Viscosity

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viscosity

The force of friction between two layers of a liquid moving past one another with different velocities is called viscosity.

A liquid may be considered to be consisting of molecular layers arranged one over the other.

A liquid flowing on a glass surface. The molecular layer in contact with the stationary surface has zero velocity. The successive layers above it move with increasingly higher velocities in the direction of the flow.

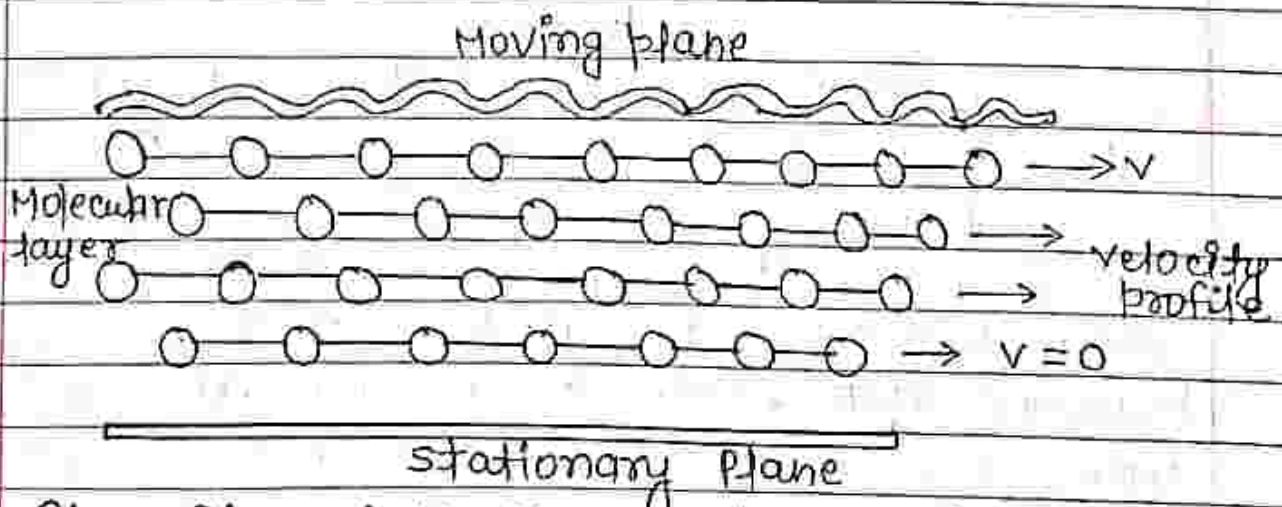


fig:- Flow of liquid on a glass surface

②

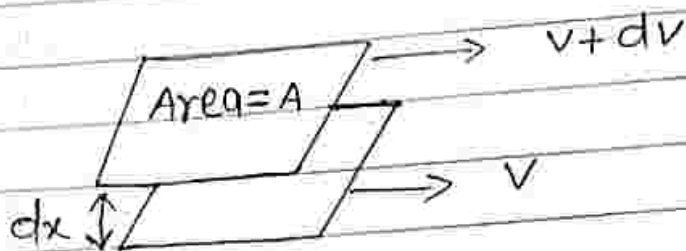


Fig:- Two Parallel layers moving in a liquid.
Let us consider two adjacent moving layers of a liquid.

Let these be separated by a distance dx and have a velocity difference dv . The force of friction (F) resisting the relative motion of the two layers is directly proportional to the area A and the velocity difference dv , while it is inversely proportional to the distance between the layers.

i.e.

$$F \propto A \frac{dv}{dx}$$

$$\text{or, } F = \eta A \frac{dv}{dx} \quad \text{--- (1)}$$

$$\therefore \eta = \frac{F}{A} \times \frac{dx}{dv} \quad \text{--- (2)}$$

where η (eta) = proportionality constant.

It is known as the co-efficient of viscosity.
from eqn (2),

The force of resistance per unit area which will maintain unit velocity difference between two layers of a liquid at a unit distance from each other is called co-efficient of viscosity.

\Rightarrow The reciprocal of viscosity is called fluidity and is denoted by ϕ .

③

$$\therefore \phi = \frac{1}{\eta}$$

The unit of fluidity is Poise⁻¹.

unit of viscosity.

The dimensions of the coefficient of viscosity (η) may be derived from eqn. (2)

$$\eta = \frac{F}{A} \times \frac{dx}{dv} = \frac{\text{force}}{\text{Area}} \times \frac{\text{distance}}{\text{velocity}}$$

$$\text{or } \eta = \frac{\text{mass} \times \text{length} \times \text{time}^{-2}}{(\text{length})^2} \times \frac{\text{length}}{\text{length}/\text{time}}$$

$$\text{or, } \eta = \text{mass} \times \text{length}^{-1} \times \text{time}^{-1}$$

Thus in CGS system the unit of η is expressed as $\text{g cm}^{-1} \text{s}^{-1}$. It is called poise (P).

Common units of viscosity are centipoise (10^{-2} Poise) and millipoise (10^{-3} poise)

The SI unit is $\text{kg m}^{-1} \text{s}^{-1}$.

one poise is equal to one-tenth of the SI unit, i.e.

$$1 \text{ Poise} = 1 \text{ g cm}^{-1} \text{ s}^{-1} = 0.1 \text{ kg m}^{-1} \text{ s}^{-1}$$

Effect of temperature on viscosity of a liquid

In general, the viscosity decreases with increase in temperature. The variation of viscosity (η) with temperature can be expressed by the following relationship

$$\eta = A e^{-E/RT} \quad \text{--- (1)}$$

where A and E are constants.

Taking logarithms on both sides, we get

$$\ln \eta = A + E/RT$$

$$\text{or } \ln \eta = \frac{E}{R} \times \frac{1}{T} + A \quad \text{--- (2)}$$

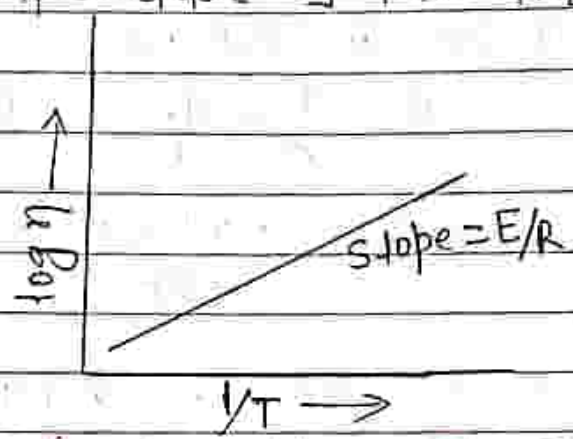
Comparing eqn. (2) with

$$Y = mx + c \quad (\text{eqn. of straight line})$$

④

A plot of $\log \eta$ versus $1/T$ should be a straight line. It has been verified for a variety of liquids.

It has also been found that there is 2% decrease in viscosity for every increase in one degree of temperature of the liquid.



Measurement of viscosity - The Ostwald Method.

The viscosity of a liquid is determined with the help of Poiseuille's equation.

This expression which governs the flow of a liquid through a capillary may be written as-

$$\eta = \frac{\pi P r^4 t}{8 l v} \quad \text{①}$$

Where v = volume of the liquid flowing through capillary in time t . P = the pressure-head, r = radius of the tube and l = length.

The viscosity of a liquid is determined with respect to that of water. This is called Relative viscosity.

Let t_1 and t_2 be the times of flow of a fixed volume (V) of the two liquids through the same capillary. The expression for relative viscosity ($\frac{\eta_1}{\eta_2}$) can be derived from equation ①

$$\frac{\eta_1}{\eta_2} = \frac{\pi P_1 r^4 t_1}{8 l V} \cdot \frac{8 l V}{\pi P_2 r^4 t_2} = \frac{P_1 t_1}{P_2 t_2} \quad \text{②}$$

(5)

Since the pressure-head is proportional to density (ρ) of the liquid, from eqn. (2) we have

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2} \quad (3)$$

Substituting the value of the viscosity of water (η_2) in eqn. (3) we can find the absolute viscosity of the given liquid (η_1).

→ η_1